5th International UHMWPE Meeting
September 22, 2011

Increasing irradiation temperature maximizes vitamin E grafting and wear resistance of UHMWPE

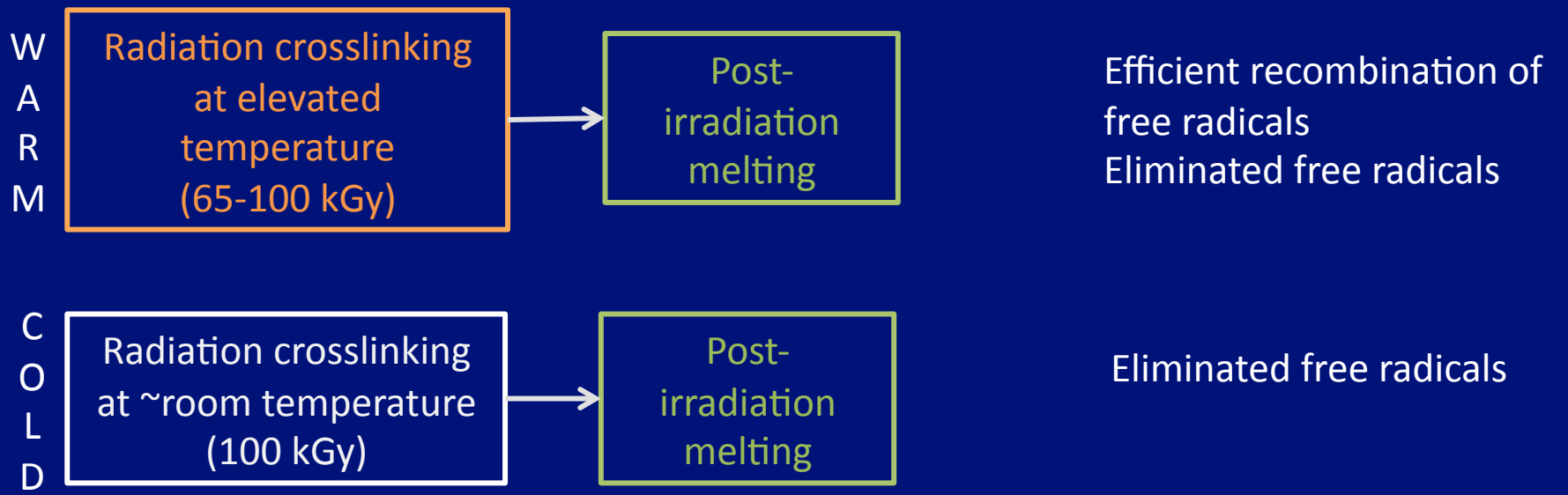
Ebru Oral, PhD; Andrew Neils, BS; Shannon L. Rowell, BS; Andrew J. Lozynsky, BS; Orhun K. Muratoglu, PhD

Harris Orthopaedic Laboratory, Massachusetts General Hospital, Boston, MA
Department of Orthopaedic Surgery
Harvard Medical School, Boston, MA

Disclosures

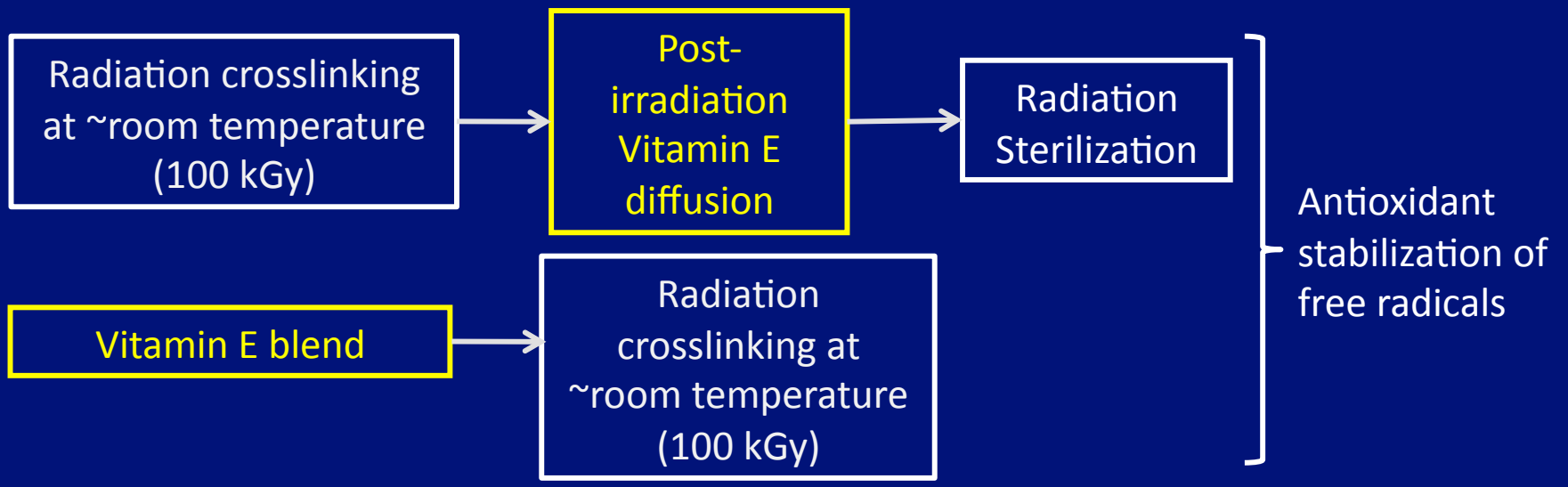
- The studies discussed here were funded by laboratory funds.
- One or more of the authors received royalties from Biomet, Inc; Zimmer, Inc; Aston Medical; Iconacy; Corin; Renovis, Conformis.
- One of the authors serves as an unpaid consultant for Biomet, Inc.
- The Harris Orthopaedic Laboratory and/or the MGH Department of Orthopaedic Surgery received institutional funds from Biomet, Zimmer, Corin, and Mako Surgical.

Alternative methods to prevent oxidation in irradiated UHMWPE



Alternative methods to prevent oxidation in irradiated UHMWPE

Vitamin E



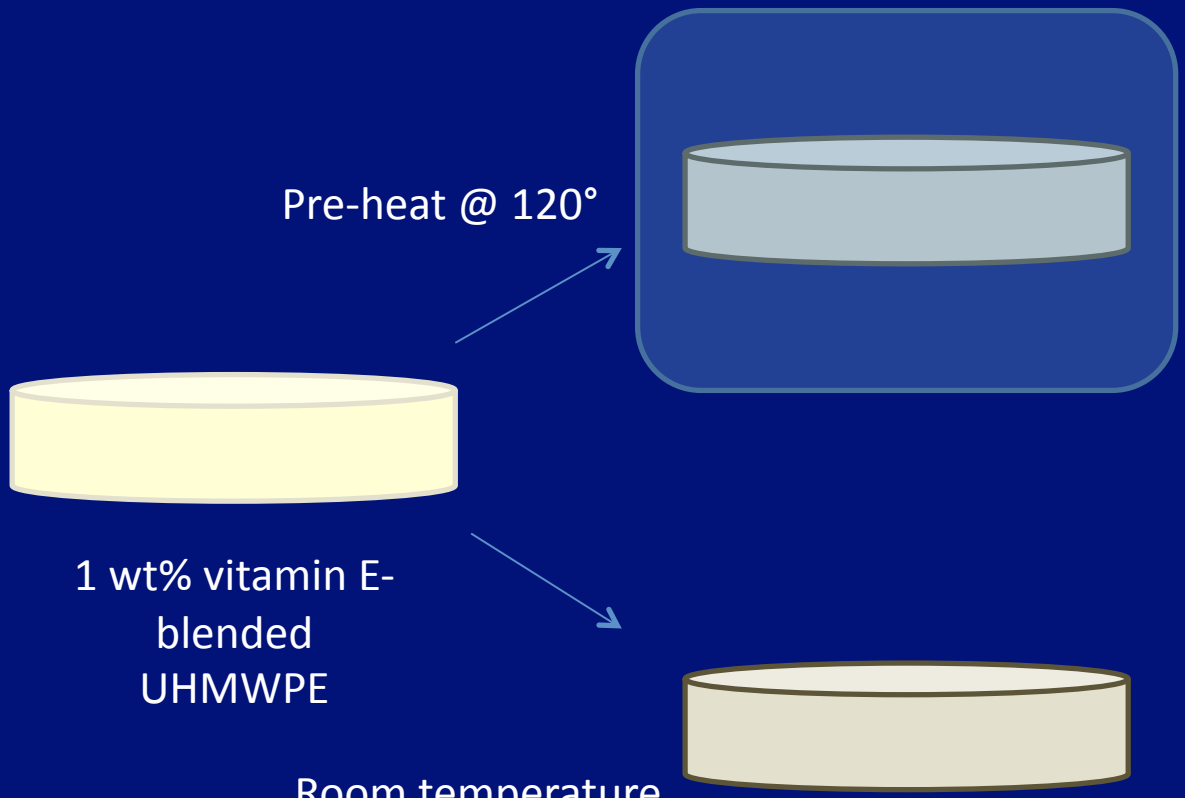
Irradiation and VitE Blends:

- Irradiation decreases VitE content
- VitE is grafted to UHMWPE

Goals

- To determine the amount of grafting in radiation cross-linked UHMWPE
- To determine the effects of irradiation at elevated temperature in the presence of vitamin E
- To compare the properties of warm irradiated vitamin E blends to warm irradiated and melted UHMWPEs

Material and Methods: Grafting

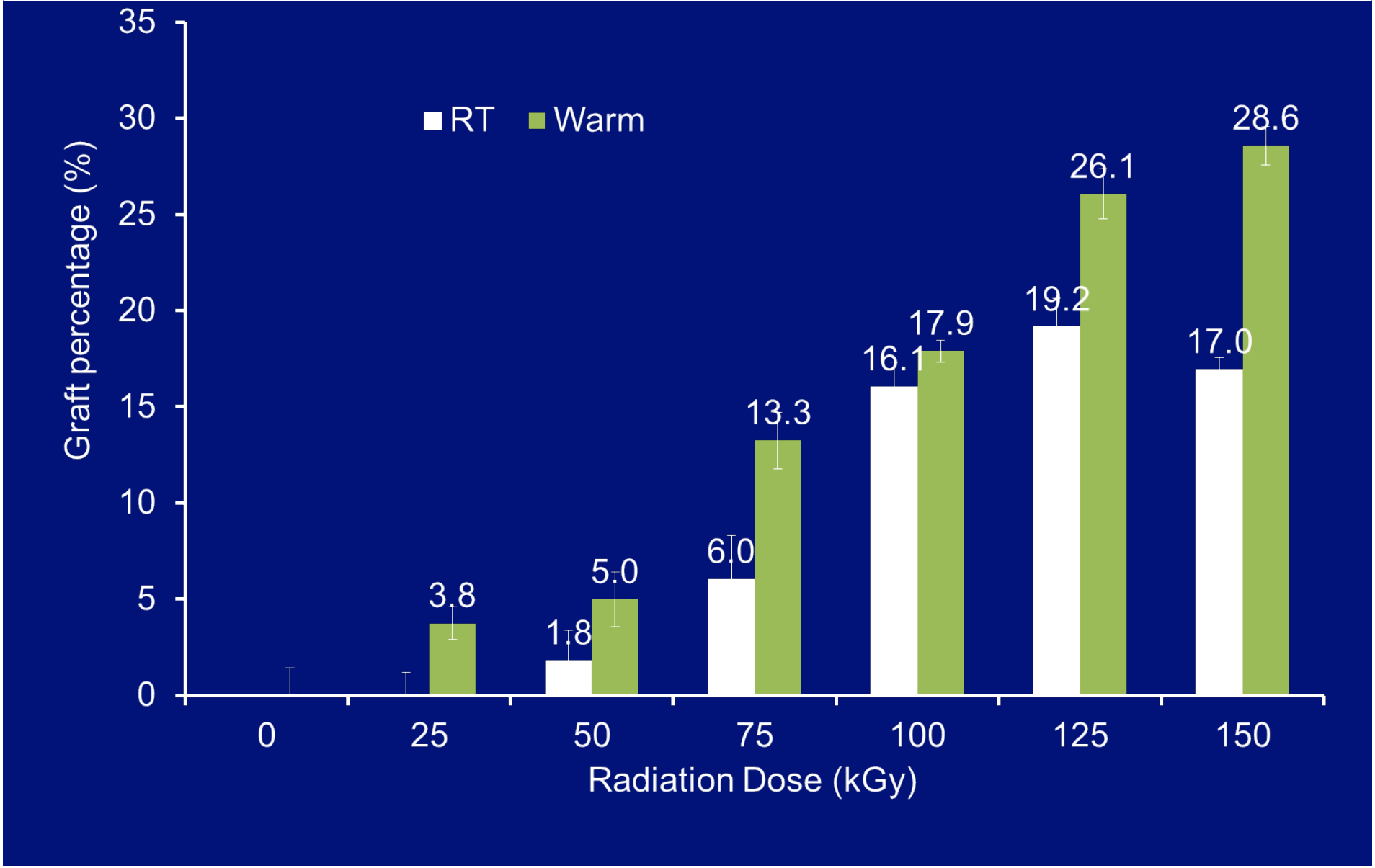


Radiation Doses:
0, 25, 50, 75, 100, 125, 150 kGy

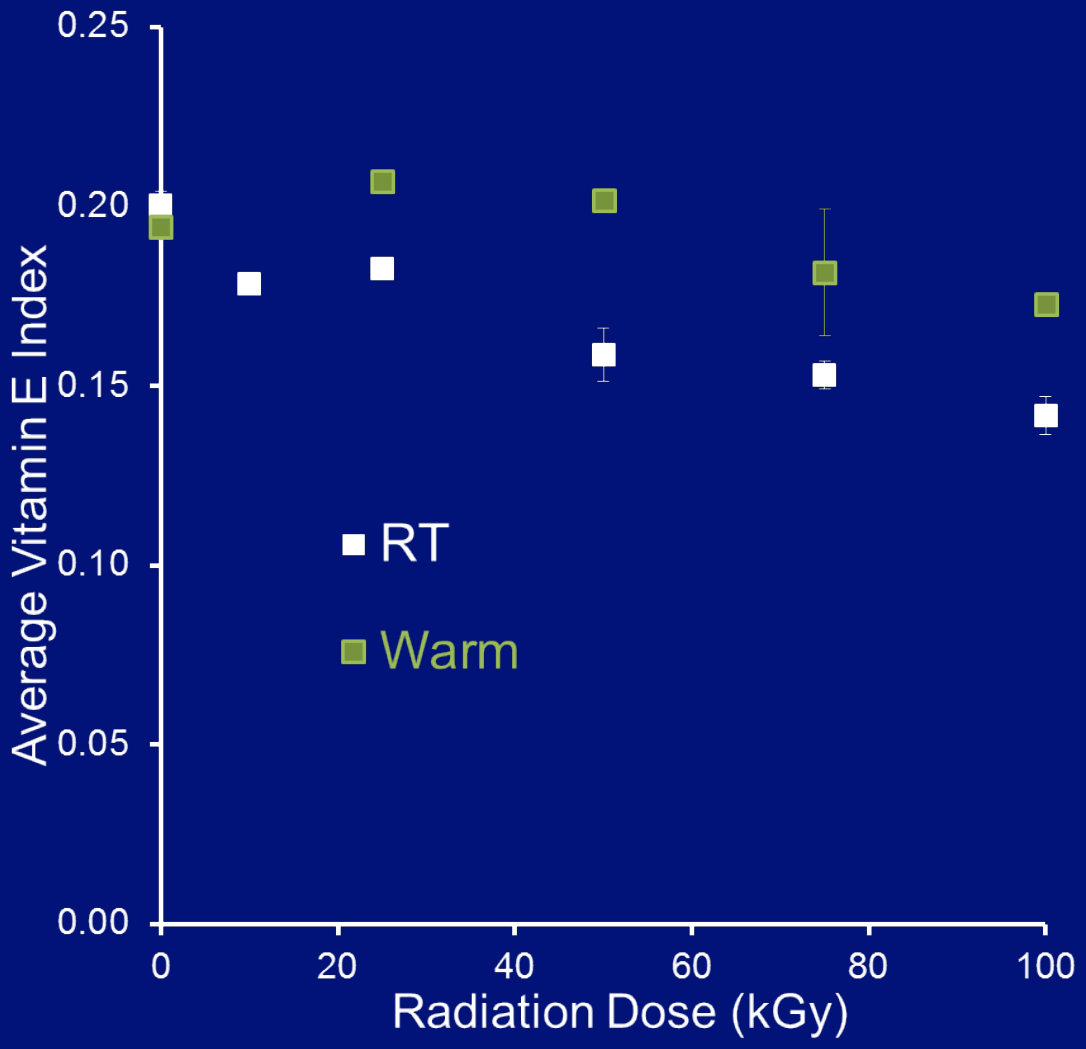
Material and Methods: Grafting

- Hexane extraction performed to remove ungrafted Vitamin E from thin films
- Assumed post-hexane VitE is grafted
- Grafting % determined through FTIR spectroscopy
  - Comparison of pre and post hexane VitE index

Vitamin E grafting is increased at elevated temperature

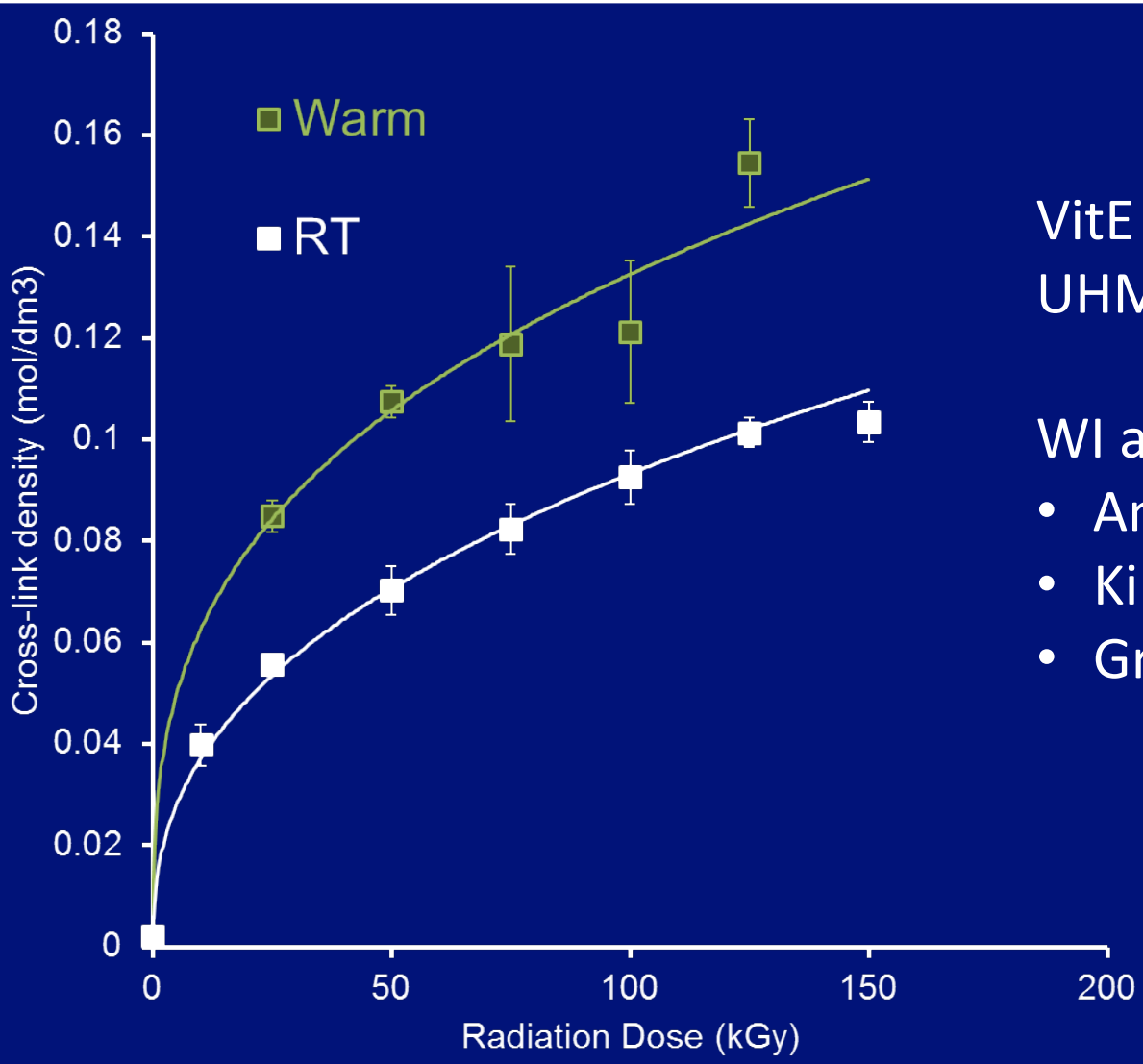


Vitamin E is preserved at elevated temperature



- FTIR scan for active phenol in VitE
- Unexpected outcome

Crosslinking increases at elevated temperature



VitE decreases Crosslinking in UHMWPE

WI affects crosslinking:

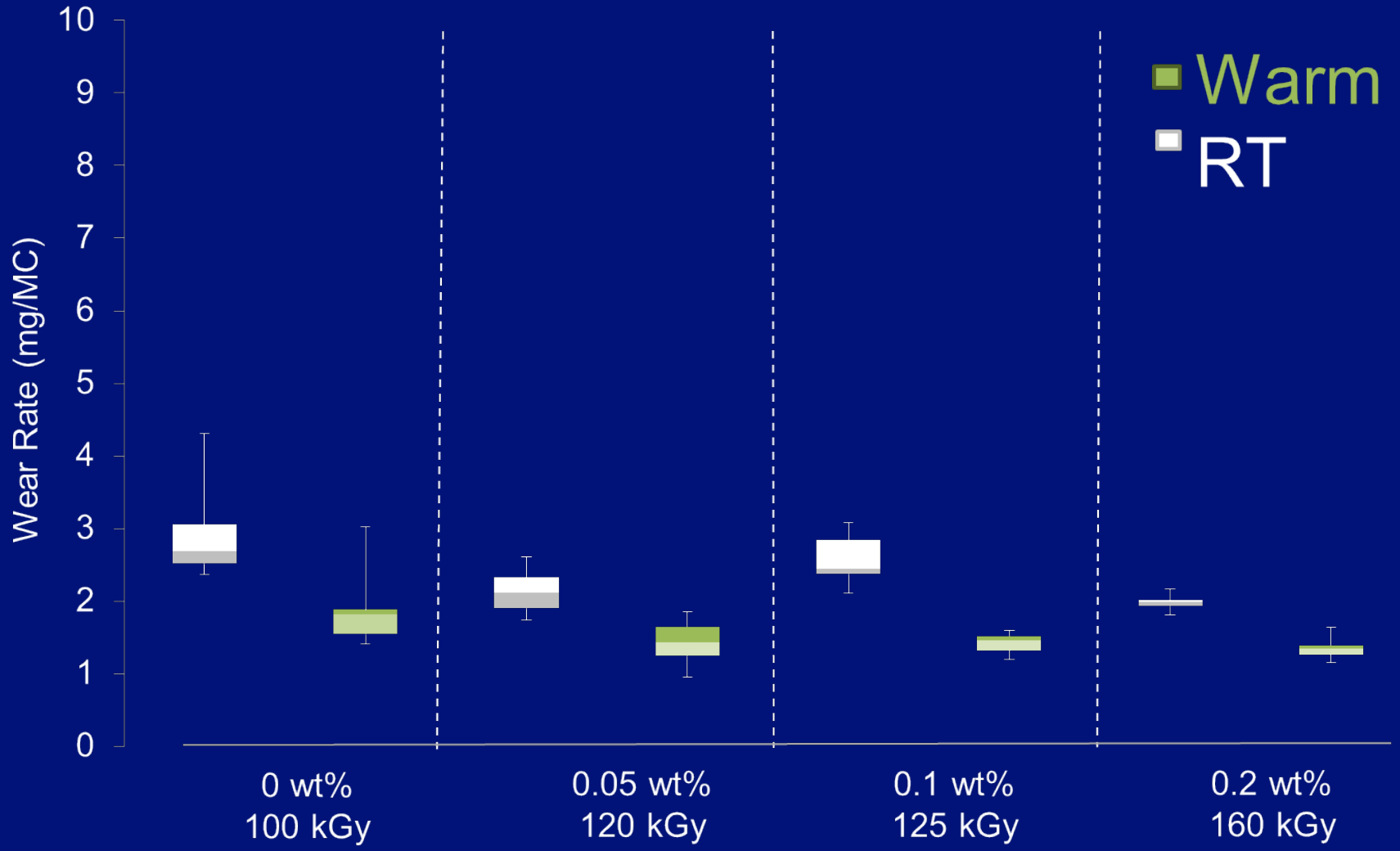
- Amorphous content
- Kinetics
- Grafting

Material and Methods: Does wear rate follow crosslink density?

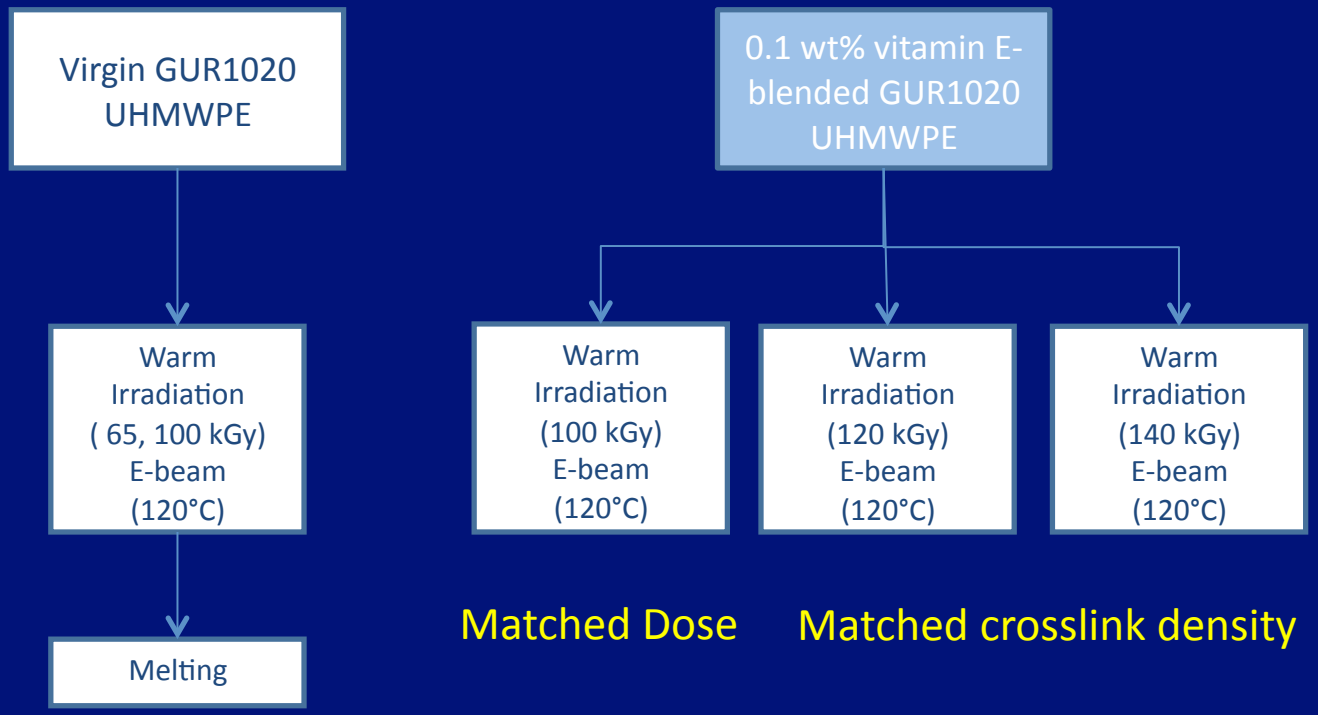
Vitamin E concentration (wt %)	Radiation dose (kGy)
-	100
0.05	120
0.1	125
0.2	160

- Radiation dose to match crosslink density
- Wear rate from bi directional pin on disc testing

Wear is decreased at elevated temperature



Material and Methods: Comparison to virgin irradiated and melted



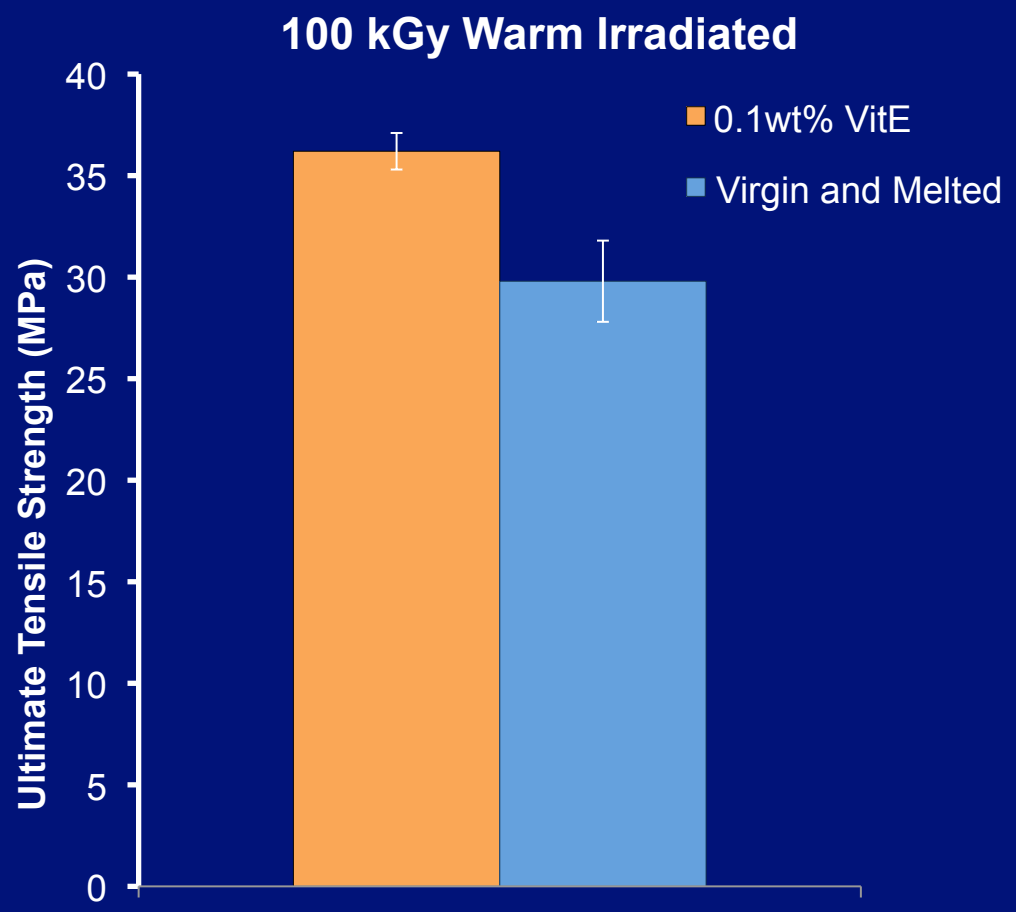
Matched Dose

	Crosslink density (mol/m^3)
65 kGy irradiated and melted virgin	169±10
100 kGy irradiated and melted virgin	209±23
0.1 wt% + 100 kGy	168±13
0.1 wt% + 120 kGy	188±5
0.1 wt% + 140 kGy	218±7

Matched
Crosslink Density

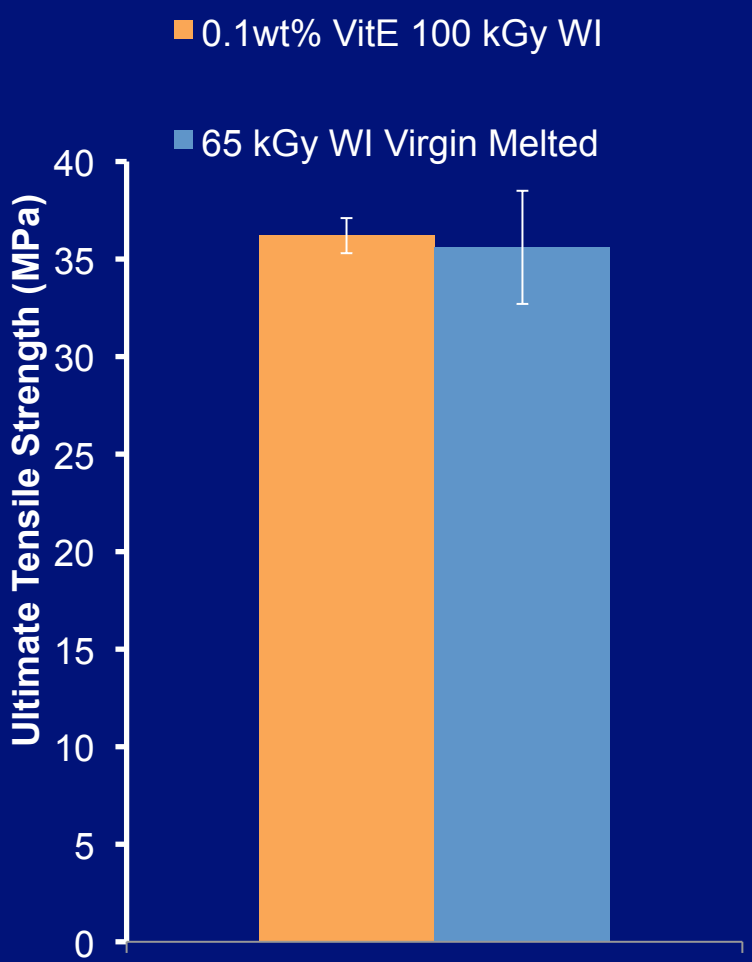
	Crosslink density (mol/m^3)
65 kGy irradiated and melted virgin	169±10
100 kGy irradiated and melted virgin	209±23
0.1 wt% + 100 kGy	168±13
0.1 wt% + 120 kGy	188±5
0.1 wt% + 140 kGy	218±7

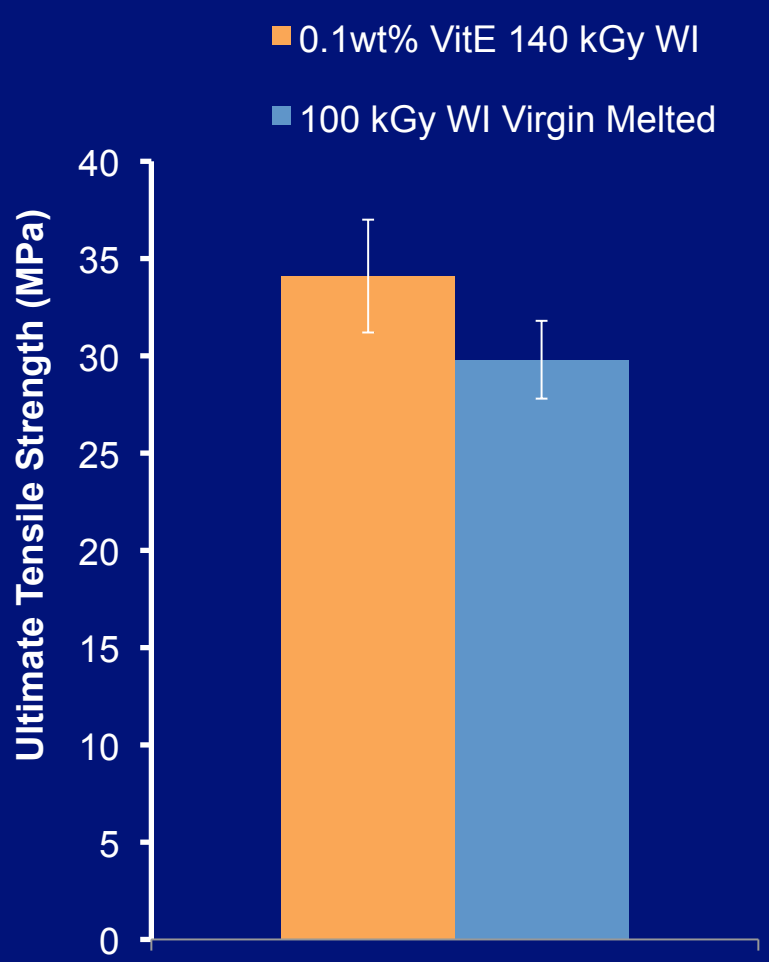
Mechanical Properties: Ultimate tensile strength



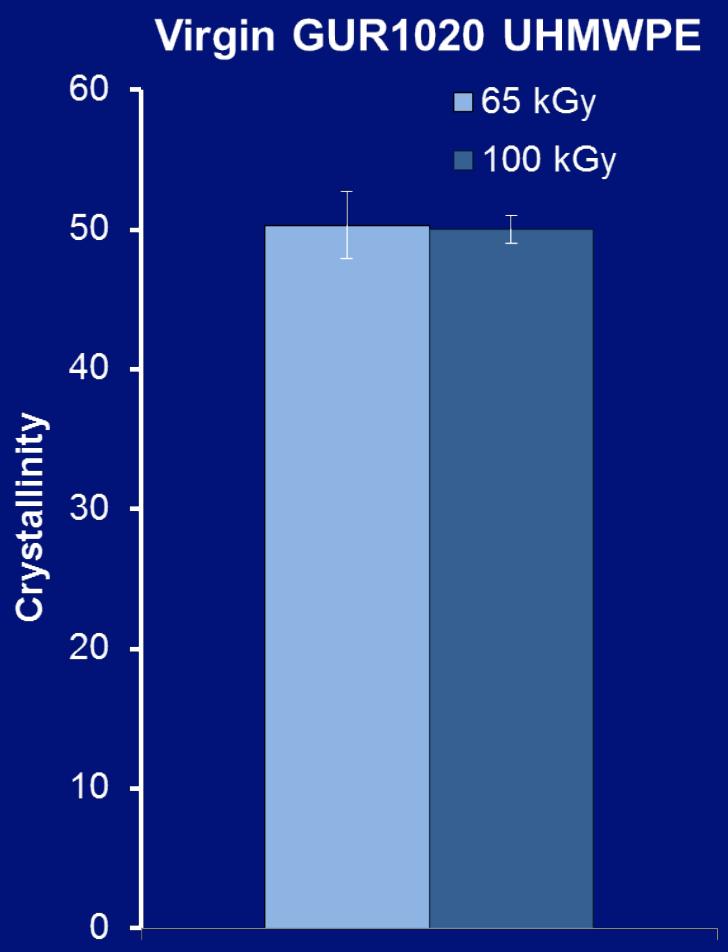
Mechanical Properties: Ultimate tensile strength

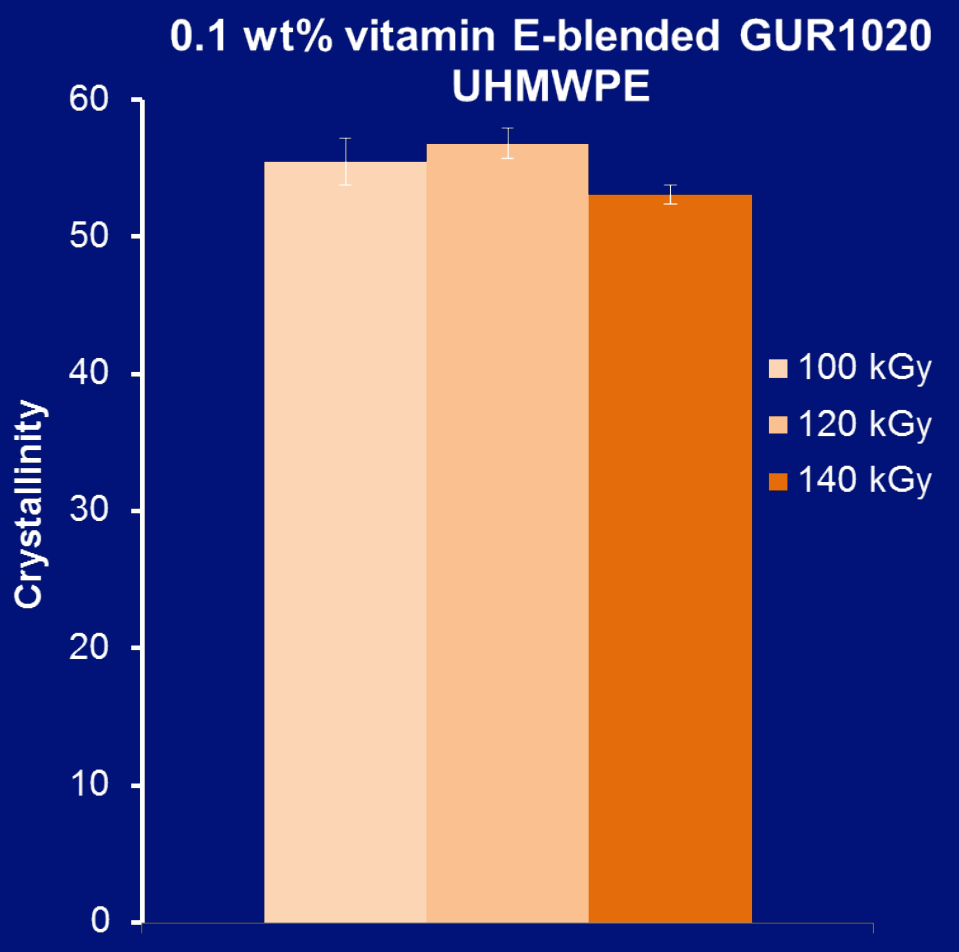
Matched Crosslink Density



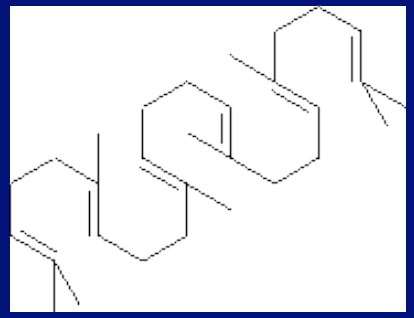


Crystallinity





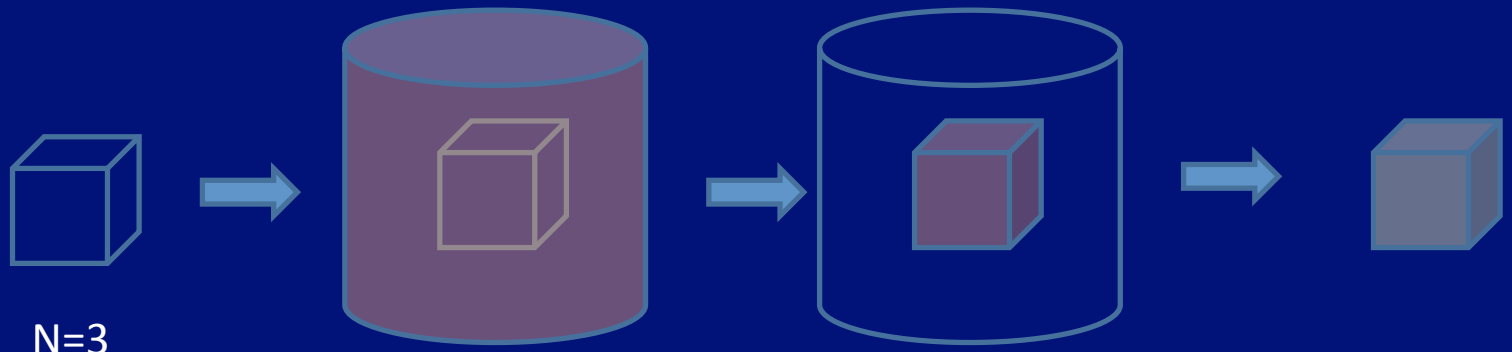
Accelerated aging with squalene



- Found to absorb in UHMWPE implants *in vivo*
  Costa et al. Biomaterials 2001 22: 307-315.

- Oxidation-prone molecule constituting large part of skin lipids
- Found in synovial fluid as well

- Useful for comparing oxidative stability. Clinical relevance TBD.

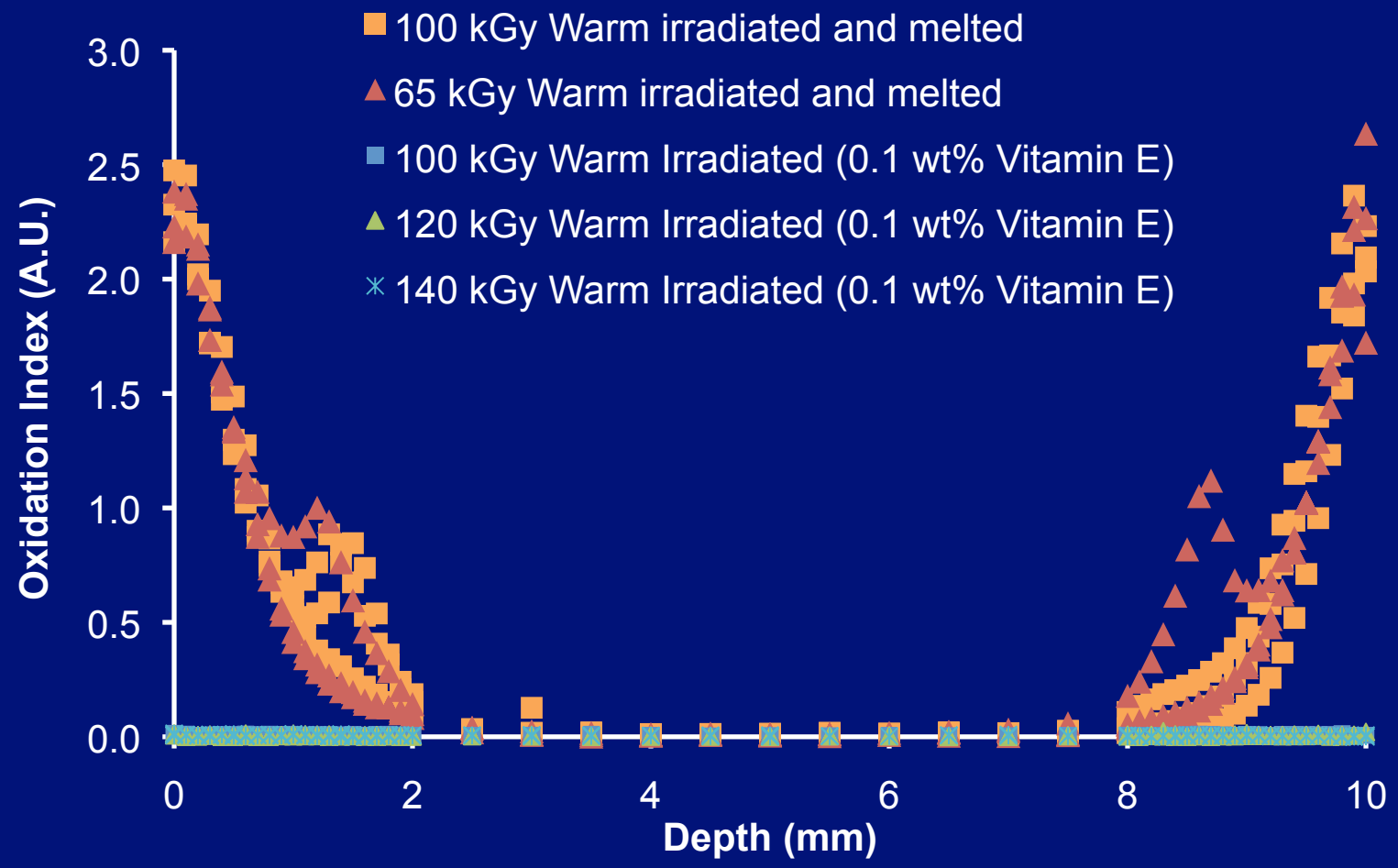


N=3

Doping in squalene
at 120°C for 2 hours

Accelerated aging in
pressure vessel at 70°C
and 5 atm. O_2

Acceleration of oxidation by lipids



Conclusions

- Warm irradiation increased the grafting of vitamin E in UHMWPE while preserving more active vitamin E for longer-term oxidative stability.

Conclusions

- Warm irradiation increased the grafting of vitamin E in UHMWPE while preserving more active vitamin E for longer-term oxidative stability.

- Warm irradiation also increased the cross-link density of the polymer and decreased the wear rate of irradiated vitamin E blends.

Conclusions

- Warm irradiation increased the grafting of vitamin E in UHMWPE while preserving more active vitamin E for longer-term oxidative stability.

- Warm irradiation also increased the cross-link density of the polymer and decreased the wear rate of irradiated vitamin E blends.

- When compared to virgin warm irradiated and melted UHMWPEs at matching cross-link density, the mechanical strength of the warm irradiated vitamin E blends were higher presumably due to higher crystallinity.

Conclusions

- Warm irradiation increased the grafting of vitamin E in UHMWPE while preserving more active vitamin E for longer-term oxidative stability.

- Warm irradiation also increased the cross-link density of the polymer and decreased the wear rate of irradiated vitamin E blends.

- When compared to virgin warm irradiated and melted UHMWPEs at matching cross-link density, the mechanical strength of the warm irradiated vitamin E blends were higher presumably due to higher crystallinity.

- When challenged in the presence of the pro-oxidant squalene, the warm irradiated vitamin E blends showed higher oxidative stability than virgin irradiated and melted UHMWPEs.

Acknowledgements

Principal Investigators:
Orhun Muratoglu, PhD (Director)
Ebru Oral, PhD
Hatice Bodugoz-Senturk, PhD

Post-doctoral Fellows:
David Bichara, MD
Jun Fu, PhD
Chhavi Gupta, PhD
Christian Wolf, PhD
Jeeyoung Choi, PhD

Students/Interns:
Pooja Yabannavar
Chelsea Lyons
Alexandra Manick
Jerel Ward

Project Managers:
Keith K. Wannomae
Shannon L. Rowell

Technical Staff:
Arnaz Malhi, MS
Sean Nabar
Andrew Neils
Mitchell Fung
Bassem W. Ghali
Christine Godleski-Beckos
Brad Micheli
Zach Konsin
Steve Christensen
Andrew J. Lozynsky

Thank You!